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(54) Title: METHODS AND SOFTWARE FOR COLOR ENCODING AND DECODING GRAYSCALE IMAGES WITHOUT PIXEL SATURATION		
(57) Abstract <p>Methods and computer programs for color encoding and decoding of grayscale images; such as images obtained by digital imaging processes (e.g., ultrasound imaging, ct scanning, mri scanning, pet scanning, etc.) or other images obtained by analog image signals that can be digitized (e.g., fluroscopy, x-ray, angiography; sonography, etc.), without pixel saturation. The invention is applicable to diagnostic imaging processes used in modern medical practice, and may also be applicable to various other medical and non-medical imaging processes such as non-destructive testing or assessment of materials, quality control of manufactured items, inspection of metals for metal fatigue or cracking, etc.</p>		
<pre> graph TD 12[Provide Black and White Digital Image (Including Bitmap Color Table and Matrix of Intensity Values)] --> 14[Copy Bitmap Color Table Into Memory to Create Temporary Bitmap Color Table] 14 --> 16[Copy Original Bitmap Color Table Into Temporary Bitmap Color Table to Create a Temporary Palette Array] 16 --> 18[Replace Ranges of Values on Temporary Bitmap Color Table with Assigned Color Values to Create Color-Modified Palette Array] 18 --> 20[Overwrite Original Bitmap Color Table with Color-Modified Palette Array While Allowing Original Matrix of Intensity Values to Remain Unmodified] 20 --> 22[Refresh Image on Screen to Generate Colorized Image Without Pixel Saturation] </pre>		

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Methods and Software for Color Encoding and Decoding Grayscale Images Without Pixel Saturation

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RELATED APPLICATION

This patent application claims priority to United States Provisional Application Serial No. 60/107,523 entitled Methods and Software for Color Encoding and Decoding Grayscale Images Without Pixel Saturation, filed on November 7, 1998, the entirety of which is expressly incorporated herein by reference.

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FIELD OF THE INVENTION

The present Invention relates generally to the field of digital imaging and, more particularly, to methods and software for colorizing digital images including, but not limited to, medical diagnostic images.

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BACKGROUND OF THE INVENTION

Digitization of analog images and the direct creation of digital images are well known in the prior art.

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An example of a method for digitizing an analog image is the use of a scanner to scan a photograph or drawing and to create a computer data file that contains a representation of the image. A computer that has been programmed with appropriate software then retrieves the computer data file and generates a digital image on a monitor, screen, or some other display device, based on the analog image information contained in the computer data file.

25

An example of a method for directly creating digitized images is medical ultrasound imaging. Diagnostic ultrasound imaging uses high frequency sound waves to observe a particular organ or anatomical region of the body. Although ultrasound equipment is very sophisticated, the procedure itself is simple and painless. A technologist applies an acoustic gel to the tip of an ultrasound transducer or probe. The transducer or probe is then placed on or in the patient's

30

The acoustical gel allows the passage of high frequency sound waves (i.e., the interrogating ultrasound) from the transducer or probe to the organ or anatomical structure of interest (e.g., heart chambers, heart valves, heart muscle, carotid (neck) arteries, the arteries and veins in the arms and legs, abdominal aorta, or renal (kidney) arteries). The interrogating ultrasound then reflects off the organ or anatomical structure of interest sending information (i.e., reflected sound waves) back to the probe. The reflected sound waves are then received by the transducer or probe and converted to a digital signal. The digital signal is then used to create a digital image on a TV screen. The digital image is stored in memory or recorded on videotape for subsequent review and interpretation. Echocardiography and Peripheral Vascular ultrasound are widely used as effective diagnostic tools for heart and blood vessel diseases.

A digital image is comprised of a two dimensional array of pixels, each of which represents a discrete portion of the two dimensional digital image. The digital images may appear to be black and white or color. Those skilled in the prior art may describe both of these images to be "color," with the black and white image being more specifically described as "grayscale." This is particularly true in the case of an 8-bit image that permits 256 levels of color.

In an 8-bit digital image, the computer assigns an R, a G, a B, and an alpha value to each pixel based on the computer data file. The R value represents the red component of the pixel, the G value represents the green component of the pixel, and the B value represents the blue component of the pixel. Each value ranges between 0 and 255. Each pixel is commonly described as having an RGB value. For example, a completely red pixel would have an RGB value of 255,0,0 in which the R component is at its maximum and the G and B components are at their minimum.

In a "grayscale" 8-bit digital image, each pixel has the ability to be black, white, and 254 shades of grey depending on the pixel's RGB value. For a grayscale image, the three components of the RGB value are equivalent. For example, the RGB value of a black pixel is 0,0,0; the RGB value of a white pixel is 255, 255, 255,

and the RGB value of a medium grey pixel is 127,127,127. The equivalent R, G, and B values in each pixel results in the components essentially canceling out any "color" being displayed on the monitor and a resulting grayscale image.

5 The computer data file containing the representation of the image may be stored as a matrix of intensity values component and a bitmap color table component. The matrix of intensity values component comprises a single value between 0 and 255 for each pixel. The bitmap color table component comprises a look up table that the computer uses to match an intensity value to an RGB value. For example, a grayscale bitmap color table matches to an intensity value of zero
10 an RGB value of 0,0,0, resulting in a black pixel. Another example is that an intensity value of 255 is associated with an RGB value of 255,255,255, resulting in a white pixel. The bitmap color table may be modified such that a "color" and not a shade of grey is associated with an intensity. For example, instead of a "black" RGB value of 0,0,0 for the lowest intensity value, the bitmap color table may assign
15 a blue RGB value of 0,0,255 for an intensity of zero.

In example of an application of the use of digital images disclosed in the prior art, color digital images are used to distinguish between vascular tissue in echocardiography. The nature of ultrasound used in echocardiography is such that the amplitude of the reflected sound waves differ based on the density of the tissues
20 that are being examined. The differences in amplitude are a result of tissue of greater density having a more intensity reflection.

A prior art approach to colorize ultrasound images is known as "B color" or "pseudo-color" process, which substitutes the grayscale image generated in echocardiography in shades of a single color, such as blue or orange. A benefit of
25 a B color process is that the endocardial edges may be better perceived. However, a drawback of the B color process is that the monochromatic shades do not distinguish between different types of tissue any better than shades of grey.

The prior art also discloses a pixel saturation colorization process useful for identifying different densities that are associated with different vascular tissues, such
30 as left ventricular muscle, fibrous tissue, or calcium. A specific example of the

process colorizes high-intensity echos of dense fibrous tissue in red and tissues of lesser density in shades of blue and green. However, the prior art colorization process takes a grayscale digital density image of 256 levels of intensity of the density and translates it to a maximum of 16 colors and 16 levels of intensity, thereby losing precision of the density measurements. The loss, through colorization, of the 256 levels of intensity is known as "pixel saturation." As a result of pixel saturation, any calculations made from the pixel saturated image have a decreased precision as well. The prior art colorization process also requires storage of the both the colorized digital image and the grayscale digital image if precise calculations are to be done, which detrimentally increases the required space to store information.

SUMMARY OF THE INVENTION

The present invention provides a method and computer program for color encoding and decoding of grayscale images, such as images obtained by digital imaging processes (e.g., ultrasound imaging, CT scanning, MRI scanning, PET scanning, etc.) or other images obtained by analog image signals that can be digitized (e.g., fluroscopy, x-ray, angiography, sonography, etc.), without pixel saturation. The invention is applicable to diagnostic imaging processes used in modern medical practice, and may also be applicable to various other medical and non-medical imaging processes such as non-destructive testing or assessment of materials, quality control of manufactured items, inspection of metals for metal fatigue or cracking, etc.

In accordance with the invention there is provided a computer program that color encodes a digitized, grayscale image any desired color for any range of intensities, without saturating the underlying pixel information. This is achieved by altering the RGB palette values that are associated with each pixel intensity, rather than changing the pixel values themselves.

Further in accordance with the invention, there is provided a method for colorizing any digital image, without pixel saturation, such method comprising the steps of a) providing a digital image that includes an original bitmap color table as

well as a matrix of intensity values, b) copying the original bitmap color table into memory so as to create a Temporary Bitmap Color Table, c) copying the original bitmap color table into the Temporary Bitmap Color Table to create a Temporary Palette Array, d) replacing ranges of values on the Temporary Bitmap Color Table with assigned color values to create a Color-Modified Palette Array, e) overwriting the original bitmap color table with the Color-Modified Palette Array while allowing the Original Matrix of Intensity Values to remain unmodified, and f) refreshing the image to generate a colorized image without pixel saturation.

Further, in accordance with the present invention, a digital image that has been colorized without pixel saturation by the foregoing method, may be converted back to the original black and white image by replacing the assigned color values with the original grayscale values, thereby de-colorizing the image and restoring its original grayscale tones.

BRIEF DESCRIPTION OF THE DRAWINGS AND APPENDIX

Figure 1 is a flow diagram showing a method for colorization of a digital image without pixel saturation.

Figure 2 is a flow diagram showing a method for de-colorization of the colorized image created by the process of Figure 1.

Figure 3 is a 5-chamber echocardiographic image that has been colorized in accordance with the present invention, whereupon an image calibration line has been drawn to calibrate the image for distance but not intensity.

Figure 4a is a 5-chamber echocardiographic image that has been colorized in accordance with the present invention, whereupon a region of interest has been delineated and an analysis has been performed to determine the percent fibrous tissue and percent calcified tissue within the region of interest.

Figure 4b is a 5-chamber echocardiographic image that has been colorized in accordance with the present invention, whereupon a region of interest has been delineated and an analysis has been performed to determine the actual area (mm²) occupied by fibrous tissue and the actual area (mm²) occupied by calcified tissue,

within the region of interest .

Figure 5a is a 5-chamber echocardiographic image that has been colorized in accordance with the present invention, whereupon a raster has been taken across the right coronary artery to obtain a density reflection profile of the right coronary artery.

Figure 5b is a raster graph showing the density reflection profile obtained from the image of Figure 5a.

Appendix A is a print out of the source code for the portions of a computer program that perform the methods of the present invention.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

The accompanying figures are provided for the purpose of illustrating certain examples of the invention and are not intended to limit or restrict the invention in any way. Reference are numerals marked on Figures 1-5b and such reference numerals are called out in the paragraphs set forth herebelow to enable the reader to direct the reader to certain portions or structures on the figures as the reader proceeds to read the detailed description set forth below.

Figure 1 is a flow chart 10 of a process for displaying digital images is shown according to an embodiment of the invention. In summary, the flow chart 10 describes the steps to generate a colorized digital image without pixel saturation from a black & white digital image.

In the first step 12 of the process 10, an original black and white digital image is provided. The black and white image is generated from a matrix of intensities and an original bitmap color table comprising grayscale RGB values. In a preferred embodiment of the invention, the black and white image is an 8-bit or 256 color grayscale image and the matrix of intensities comprise values of in a range of between 0 and 255. Other embodiments of the invention may have different ranges for the intensity values.

The original bitmap color table of the black and white digital image is a look-up table that a computer uses to assign RGB values to each pixel of the image

based on the associated intensity values. A computer is defined as any computation device that is directed at least in part by machine readable code, and the machine readable code may be in form of software, hardware, or a combination of the two. An example of hardware is a functionally connected preprogrammed computer chip or other permanent data storage device. In the preferred embodiment of the invention, the original black and white digital image is displayed on a screen. A screen is defined as any device from which a user views the black and white digital image, for example, a computer monitor or projection device.

In a preferred embodiment of the invention, the original bitmap color table assigns a four part value for each intensity value. The first three values determine the color of each pixel in the image, or the RGB values. Each RGB value is the same as the intensity of each segment. For example, for an intensity of 0, the RGB value is 0,0,0, which results in a black pixel. For an intensity of 255, the RGB value is 255,255,255, which results in a white pixel. Intensities between 0 and 255 result in a grey pixel which has a larger white component the greater the intensity value. The fourth value, or the alpha value, is not used in the preferred embodiment of the invention.

In a next step 14 of the preferred embodiment of the invention, a temporary bitmap color array is defined in the memory of a computer. This step 14 may be performed by the sub-routine entitled GETVICPALETTE of the computer program source code appended hereto as Appendix A. The temporary bitmap color array is defined to enable the original bitmap color table to be copied thereinto. This step is not necessary in some embodiments of the invention, which depends on the language of the machine readable code.

In a further step 16 of the preferred embodiment of the invention, the original bitmap color table comprising grayscale RGB values is copied into the predefined bitmap color table array. This step 16 may also be performed by the sub-routine entitled GETVICPALETTE of the computer program source code appended hereto as Appendix A.

Next, in step 18, the grayscale RGB values are replaced with assigned RGB

values. This step 18 may performed by the sub-routine entitled CHANGECOLOR of the computer program source code appended hereto as Appendix A. The assigned RGB values are based on what colors are to represent what ranges of intensity values. For example, intensity values having a range of 0-50 are assigned to be red, intensity values having a range of 51-125 are assigned to be orange, intensity values having a range of 126-200 are assigned to be yellow, and intensity values having a range of 201-255 are assigned to be blue, each of which has an associated RGB value that produces the desired pixel color.

In an embodiment of the invention, the assignment of the RGB values for each range of intensity values is predefined in the machine readable code that directs the computer. In other embodiments of the invention, the intensity ranges and the RGB values for each range are assigned by the user of the computer. In still other embodiments of the invention, the user may modify the machine readable code to change the predefined assigned RGB values for the intensity ranges, change the intensity ranges, or a combination of the two.

In another step 120 of the invention, the image on the screen is refreshed to generate a colorized image without pixel saturation. This step 120 may performed by the sub-routines entitled SETVICPALETTE and CHANGECOLOR of the computer program source code appended hereto as Appendix A. The colorized image is generated from the matrix of intensity values and the assigned RGB values in the temporary bitmap color array.

In a preferred embodiment of the invention, the matrix of intensity values is preserved or saved, thus colorizing the black and white image does not result in loss of intensity values. This aspect of the invention permits the user, or a machine readable code, to direct the computer to analyze at least a portion of the colorized image without loss of the precision of the underlying matrix of intensity values. For example, a portion of the colorized image, such as an area, is selected and analyzed as a function of the matrix of intensity values associated with the colorized image portion. An example of an analysis is that the percentage of pixels in the portion of the colorized image associated with intensity values of a specific range

or a set of ranges. Another analysis example is a raster that is defined by the user on the colorized image and a line plot of the intensity values associated with the pixels through which the raster is drawn is created. Other embodiments of the invention comprise other analytic procedures, some of which as described below in more detail.

Also, in a preferred embodiment of the invention, the computer stores or preserves the original matrix of intensity values, thus reducing the amount of computer memory required to reproduce both color and black and white digital images. Other embodiments of the invention may store both the colorized digital image and the black and white digital image.

Referring now to Figure 2, a flow chart 130 discloses the steps in an embodiment of the invention to convert the colorized digital image back into a black and white digital image. In step 132, the colorized digital image generated from the matrix of intensity values and the RGB values in the temporary bitmap color array are provided. In step 134, the bitmap color table of the image provided in step 132 is copied into memory to create a Temporary Bitmap Color Table. This step 134 may performed by the sub-routine entitled GETVICPALETTE of the computer program source code appended hereto as Appendix A.

Thereafter, in step 136, the bitmap color table of the colorized image provided in step 132 is copied into the Temporary Bitmap Color Table created in step 134 to thereby create a Color-Modified Palette Array. This step 136 may performed along with step 134 by the sub-routine entitled GETVICPALETTE of the computer program source code appended hereto as Appendix A. Thereafter, in step 138, the assigned color values contained in the bitmap color table are replaced with the grayscale values from the original black and white image (step 12 of Figure 1) to create a Non-Color-Modified Palette Array. This step 138 may performed by the sub-routine entitled REMOVECOLOR of the computer program source code appended hereto as Appendix A.

In step 140, the original bitmap color table of the colorized image (provided in step 132) is then overwritten with the non-color-modified Palette Array while

allowing the original matrix of intensity values to remain unmodified. After such
overwriting has been accomplished, the image on the screen is refreshed, thereby
providing the original black and white digital image that existed in step 12 of figure
1. This step 140 may performed by the sub-routines entitled SETVICPALETTE and
5 REMOVECOLOR of the computer program source code appended hereto as
Appendix A.

In other embodiments of the invention, another colorized digital image is
generated by replacing the RGB values in the temporary bitmap color array with
another set of assigned RGB values. The other set of assigned RGB values result
10 in the other colorized digital image when the image on the screen is refreshed.

Embodiments of the invention may be used to generate and analyze images
representing property characteristics of an object. Specific examples of objects and
property characteristics are described below. Some general examples of objects
are body parts of patients, exteriors of structures, manufactured parts, and any other
15 object that is representable with a digital image. The digital images may be
generated through ultrasound imaging, CT scanning, MRI scanning, PET scanning
directly. In other embodiments of the invention, the image is produced by analog
image signals that are subsequently digitized, such as those produced through
fluoroscopy, x-ray, angiography, sonography for example. Embodiments of the
20 invention may be used to analyze for density, structural integrity, thermodynamic
properties for example.

As discussed hereabove, one area in which the invention is particularly
applicable is in the colorization of diagnostic medical images, such as images of the
heart and blood vessels obtained by cardiac ultrasound (e.g., echocardiography, M-
25 mode echocardiography, transesophageal echocardiography, etc...). After a black
and white digital image produced through coronary ultrasound (i.e.,
echocardiography) is converted to a colorized image, tissue having different
densities is represented through different colors. Because that colorized digital
image has not undergone pixel saturation, a densitometric analysis may be
30 performed. In a preferred embodiment of the invention, the colorized image is

stored in a file format that supports palette color information, such as PCX (*.pcx).

The visual identification of the different tissue represented in the digital image is enhanced through the choice of colors representing the different tissue. It is well known by those skilled in the art that the different tissues of interest represented in the digital image have differing mean densities. In an embodiment of the invention, the left ventricular muscle, which has a density such that the intensity values of it fall in a range of 30 through 69, is represented by blue-green and the RGB values are (0, 128, 128) for it. Fibrous tissue, or more specifically atherosclerotic plaque that is considered to be Grade 2 under the American Heart Association classification scheme, which has a density such that the intensity values of it fall in a range of 70 through 199, is represented by red and the RGB values are (128, 0,0). Calcified tissue, or more specifically Grade 3 antherosclerosis under the AHA classification scheme, which has a density such that the intensity values of it fall in a range of 200 through 255, is represented by white and the RGB values are (255, 255, 255)

Other embodiments of the invention may have other colors associated with the different types of tissue. In a still further embodiment of the invention, blue on gold images are produced by subtracting predetermined density levels such that fibrosis is emphasized..

The use of the present invention in lieu of prior art methods for colorization of digital images results in a colorized image from which specific measurements of relative object (e.g., tissue) densities mat be obtained. In applications related to a cardiac ultrasound image, the method and computer program of the present invention may be used to assess coronary calcium, fibrosis, plaque topography, and the like. In this regard, Examples 1-3 set forth herebelow (and the corresponding Figures 3a-5b) illustrate uses of the present invention to analyze tissue densities and to determine coronary fibrosis & calcification, from cardiac ultrasound images that have been colorized, without pixel saturation, in accordance with the present invention.

EXAMPLE I

(Measurement of Relative Amounts of Fibrous and Calcified Tissue Within A Defined Region of a Coronary Ultrasound Image)

Figure 3, 4a and 4b show 5-chamber echocardiographic images 300, 320, 340 of the coronary vasculature of a human patient. The images 300, 320, 340 of Figures 3, 4a and 4b have been colorized, without pixel saturation, in accordance with the method described hereabove and shown in Figure 1.

As shown on Figure 3, the computer is initially calibrated for distance by marking a line 302 adjacent the image 300 and inputting the known distance, in centimeters, to be assigned to the length of the line 302. The computer program of this invention then establishes a pixel per unit length calibration on this basis.

As shown in Figure 4a, after the distance calibration has been completed, an area of interest is delineated by the creation of a perimeter marking 322 on the image screen. This perimeter marking 322 may be a rectangle as shown in Figure 4a or any other symmetrical or non-symmetrical area-defining marking. In the case of Figure 4a, the perimeter marking 322 is positioned over a portion of the left anterior descending coronary artery. Thereafter, the operator inputs an instruction for the computer to determine the amount of fibrous and calcified tissue within the perimeter marking 322 by clicking the "analyze fibrous tissue" icon 325 within the tissue analysis window 323. The computer program then calculates, on the basis of the image intensity values for the portion of the image that is within the perimeter marking 322, the relative percentages of fibrous and calcified tissue present within that area of interest. The percentage of fibrous tissue 324 and the percentage of calcified tissue 326 are then displayed in the tissue analysis window 323, as shown. In the showing of Figure 4a, the computer has determined that 8.8%

percent of the tissue within the perimeter marking 322 is fibrous and 0.0% of the tissue within the perimeter marking 322 is calcified.

Figure 4b shows another image 340 wherein a tissue density analysis is obtained by the same methodology as described hereabove in this example, but wherein the computer program is instructed by the operator to determine the actual area (in mm²) within a perimeter marking 322a located over the right coronary artery that is occupied by fibrous and calcified tissues. As shown in Figure 4b, the tissue analysis window now displays the fibrous tissue area 324b and the calcified tissue area 326b within the perimeter marking 322b. In this case, 3507.8 mm² is occupied by fibrous tissue and 1379.3 mm² is occupied by calcified tissue.

EXAMPLE II

(Raster Analysis of Tissue Density)

Figures 3 and 5a show 5-chamber echocardiographic images 300, 360 of the coronary vasculature of a human patient. Figure 5b shows a density graph profile that corresponds to the image 360 shown in Figure 5a. The echocardiographic images 300, 360 Figures 3 and 5a have been colorized, without pixel saturation, in accordance with the method described hereabove and shown in Figure 1.

As shown on Figure 3, the computer is initially calibrated for distance by marking a line 302 adjacent to the image 300 and inputting the known distance, in centimeters, to be assigned to the length of the line 302. The computer program of this invention then establishes a pixel per unit length calibration on this basis.

As shown in Figure 5a, after the distance calibration has been completed, an area of interest is delineated by a raster line 362 which is marked on the image screen over the area of interest, such as a segment of the right coronary artery. Thereafter the operator instructs

the computer program to generate a density profile graph 364 for the tissue that underlies the raster line 362. The computer then generates such density profile based on the image intensity values of the pixels of the image 360 that underlie the raster line 362. Such density profile graph 364 is shown in Figure 5b, and represents the density reflection profile of the segment of the right coronary artery located under the raster line 362.

The machine readable code may be a computer program that is burned into a chip or stored on a magnetic medium or any other suitable medium. The machine readable code may be written in any suitable computer language. The portions of the source code appended hereto as appendix A are examples of the manner in which the machine readable code of this invention may be written in the Visual BASIC language.

It is to be appreciated that the invention has been described herein with reference to certain specific examples, and no attempt has been made to exhaustively describe all possible examples and embodiments in which the invention may be practiced. Indeed, various additions, deletions, modifications and alterations may be made to the particular embodiments and examples described herein, without departing from the intended spirit and scope of the invention. Accordingly, it is intended that all such additions, deletions, alterations and modifications be included within the scope of the following claims and/or the equivalents thereof.

APPENDIX A

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Dim sngTim As Single
sngTim = Val(GetTim)

timcalib(Me.tag) = C(Me.tag) / sngTim

Dim CalibOK As String
CalibOK = MsgBox("Time calibration: " & Format(timcalib(Me.tag), SFormat) & " pixels per sec
ond", vbOKOnly, "Time Calibration Successful!")

End Sub
Private Sub mnuImageCalibVeloc_Click()
    If C(Me.tag) = 0 Then
        Dim NeedCalib As String
        NeedCalib = MsgBox("You need to use the line selection tool to draw a line between at le
ast two velocity markers.", vbInformation, "Velocity Calibration")
        Exit Sub
    End If

    If GraphNow(Me.tag) = False Then
        NeedCalib = MsgBox("You need to use the line selection tool to draw a line between at le
ast two velocity markers.", vbInformation, "Velocity Calibration")
        Exit Sub
    End If

    Dim GetVel As String
    GetVel = InputBox("How many m/sec does this line represent? (min = 0)", "Velocity Calibratio
n")
    If GetVel = "" Then
        Exit Sub
    End If

    Dim sngVel As Single
    sngVel = Val(GetVel)

    velcalib(Me.tag) = C(Me.tag) / sngVel

    Dim CalibOK As String
    CalibOK = MsgBox("Velocity calibration: " & Format(velcalib(Me.tag), SFormat) & " pixels per
m/sec", vbOKOnly, "Calibration Successful!")

End Sub
Public Sub mnuImageConvertColor_Click()
    ChangeColor
End Sub
Public Sub RemoveColor()
    Dim j As Integer
    Dim red As Integer
    Dim grn As Integer
    Dim blu As Integer
    Dim pal As OUR_PALETTE
    rcode = NO_ERROR

    If vimage(Me.tag).colors = 0 Then rcode = BAD_BPP

    GetVicPalette pal, vimage(Me.tag)

    ' Normal muscle tissue

    For j = 0 To 255
        red = pal.palentry(j).rgbRed
        grn = pal.palentry(j).rgbGreen
        blu = pal.palentry(j).rgbBlue

        red = j
        grn = j
        blu = j

        pal.palentry(j).rgbRed = red
        pal.palentry(j).rgbGreen = grn

```

```

    pal.palentry(j).rgbBlue = blu
Next j

```

```

'-----
' Now get the filename and file info from this window

```

```

    If GraphNow(Me.tag) = True Then
    Dim bm As BITMAPINFOHEADER
    Getbmhfromimage bm, vimage(Me.tag)
    vimage(Me.tag).stx = 0
    vimage(Me.tag).sty = 0
    vimage(Me.tag).EndX = bm.biWidth - 1
    vimage(Me.tag).EndY = bm.biHeight - 1
    End If

```

```

Dim bmh As BITMAPINFOHEADER
Dim bitcount As Long
Dim width As Long
Dim height As Long

```

```

'Get bitcount, width, and height values

```

```

Getbmhfromimage bmh, vimage(Me.tag)

```

```

'Convert to long variable forms

```

```

bitcount = bmh.biBitCount
width = bmh.biWidth
height = bmh.biHeight

```

```

' Get info for new image based on current Filename & extension

```

```

Dim fileType As String
fileType = LCase$(right$(Me.Caption, 3))

```

```

' Get new index for new buffer and window

```

```

Dim findex As Integer
findex = FindFreeIndex()
Document(findex).tag = findex
Document(findex).Caption = "Untitled(" & findex & ")." & fileType

```

```

' Allocate new buffer based on abs value differences
' between X1/X2 and Y1/Y2.

```

```

If CropNow(Me.tag) = True Then
    rcode = Module1.reallocimage(vimage(findex), (Abs(X2(Me.tag) - X1(Me.tag)) + 1), (Abs(Y2(Me.
tag) - Y1(Me.tag)) + 1), bitcount, findex)
End If

```

```

' Or, allocate new buffer based on dimensions of original image

```

```

If CropNow(Me.tag) = False Then
    rcode = Module1.reallocimage(vimage(findex), width, height, bitcount, findex)
End If

```

```

If rcode <> NO_ERROR Then
    frmImage.error_handler rcode, ""
End If

```

```

Screen.MousePointer = 11
' Copy image from old to new buffer

```

```

rcode = copyimage(vimage(Me.tag), vimage(findex))
If rcode <> NO_ERROR Then
    frmImage.error_handler rcode, ""
End If

```

```

' Set new palette to the new image, update its palette

SetVicPalette pal, vimage(findex)
rcode = updatebitmapcolortable(vimage(findex))
If rcode <> NO_ERROR Then
    frmImage.error_handler rcode, ""
End If
' Housekeeping stuff; set-up revert and undo buffers for new window

rcode = copyimage(vimage(findex), zimage(findex))
rcode = copyimage(vimage(findex), revimage(findex))
rcode = copyimage(vimage(findex), uimage(findex))

' Set new calibration values to old ones (same image!)
lincalib(findex) = lincalib(Me.tag)
velcalib(findex) = velcalib(Me.tag)
timcalib(findex) = timcalib(Me.tag)

' Set Dirty state of new window to True
FState(findex).Dirty = True

' Paint and refresh this new window
    EnableToolBar

    Document(findex).Form_Resize
    Document(findex).Show
    FState(findex).Open = True
    Document(findex).form_paint

    Document(findex).Refresh

    GetRecentFiles

    Screen.MousePointer = 0

End Sub
Public Sub ChangeColor()

Dim j As Integer
Dim red As Integer
Dim grn As Integer
Dim blu As Integer
Dim pal As OUR_PALETTE
rcode = NO_ERROR

If vimage(Me.tag).colors = 0 Then rcode = BAD_BPP

GetVicPalette pal, vimage(Me.tag)

' Normal muscle tissue

For j = 0 To 15
    red = pal.palentry(j).rgbRed
    grn = pal.palentry(j).rgbGreen
    blu = pal.palentry(j).rgbBlue

    red = 0
    grn = 0
    blu = 0

    pal.palentry(j).rgbRed = red
    pal.palentry(j).rgbGreen = grn
    pal.palentry(j).rgbBlue = blu
Next j

For j = 16 To 31

```

```
red = pal.paentry(j).rgbRed
grn = pal.paentry(j).rgbGreen
blu = pal.paentry(j).rgbBlue

red = 64
grn = 64
blu = 64

pal.paentry(j).rgbRed = red
pal.paentry(j).rgbGreen = grn
pal.paentry(j).rgbBlue = blu
Next j

For j = 32 To 47
red = pal.paentry(j).rgbRed
grn = pal.paentry(j).rgbGreen
blu = pal.paentry(j).rgbBlue

red = 0
grn = 0
blu = 128

pal.paentry(j).rgbRed = red
pal.paentry(j).rgbGreen = grn
pal.paentry(j).rgbBlue = blu
Next j

For j = 48 To 63
red = pal.paentry(j).rgbRed
grn = pal.paentry(j).rgbGreen
blu = pal.paentry(j).rgbBlue

red = 0
grn = 128
blu = 0

pal.paentry(j).rgbRed = red
pal.paentry(j).rgbGreen = grn
pal.paentry(j).rgbBlue = blu
Next j

For j = 64 To 69
red = pal.paentry(j).rgbRed
grn = pal.paentry(j).rgbGreen
blu = pal.paentry(j).rgbBlue

red = 0
grn = 128
blu = 128

pal.paentry(j).rgbRed = red
pal.paentry(j).rgbGreen = grn
pal.paentry(j).rgbBlue = blu
Next j

' Fibrous Tissue
For j = 70 To 199
red = pal.paentry(j).rgbRed
grn = pal.paentry(j).rgbGreen
blu = pal.paentry(j).rgbBlue

red = 128
grn = 0
blu = 0

pal.paentry(j).rgbRed = red
pal.paentry(j).rgbGreen = grn
pal.paentry(j).rgbBlue = blu
```

```

Next j
' Calcium
For j = 200 To 255
    red = pal.palentry(j).rgbRed
    grn = pal.palentry(j).rgbGreen
    blu = pal.palentry(j).rgbBlue

    red = 255
    grn = 255
    blu = 255

    pal.palentry(j).rgbRed = red
    pal.palentry(j).rgbGreen = grn
    pal.palentry(j).rgbBlue = blu
Next j

'-----
' Now get the filename and file info from this window

If GraphNow(Me.tag) = True Then
    Dim bm As BITMAPINFOHEADER
    Getbmhfromimage bm, vimage(Me.tag)
    vimage(Me.tag).stx = 0
    vimage(Me.tag).sty = 0
    vimage(Me.tag).EndX = bm.biWidth - 1
    vimage(Me.tag).EndY = bm.biHeight - 1
End If

Dim bmh As BITMAPINFOHEADER
Dim bitcount As Long
Dim width As Long
Dim height As Long

'Get bitcount, width, and height values
Getbmhfromimage bmh, vimage(Me.tag)

'Convert to long variable forms

bitcount = bmh.biBitCount
width = bmh.biWidth
height = bmh.biHeight

' Get info for new image based on current Filename & extension

Dim fileType As String
fileType = LCase$(right$(Me.Caption, 3))

' Get new index for new buffer and window
Dim findex As Integer
findex = FindFreeIndex()
Document(findex).tag = findex
Document(findex).Caption = "Untitled(" & findex & ")." & fileType

' Allocate new buffer based on abs value differences
' between X1/X2 and Y1/Y2.

If CropNow(Me.tag) = True Then
    rcode = Module1.reallocimage(vimage(findex), (Abs(X2(Me.tag) - X1(Me.tag)) + 1), (Abs(Y2(Me.
tag) - Y1(Me.tag)) + 1), bitcount, findex)
End If

' Or, allocate new buffer based on dimensions of original image
If CropNow(Me.tag) = False Then

```

```

        rcode = Module1.reallocimage(vimage(findex), width, height, bitcount, findex)
    End If

    If rcode <> NO_ERROR Then
        frmImage.error_handler rcode, ""
    End If

    Screen.MousePointer = 11
    ' Copy image from old to new buffer

    rcode = copyimage(vimage(Me.tag), vimage(findex))
    If rcode <> NO_ERROR Then
        frmImage.error_handler rcode, ""
    End If
    'Set new palette to the new image, update its palette

    SetVicPalette pal, vimage(findex)
    rcode = updatebitmapcolortable(vimage(findex))
    If rcode <> NO_ERROR Then
        frmImage.error_handler rcode, ""
    End If
    ' Housekeeping stuff; set-up revert and undo buffers for new window

    rcode = copyimage(vimage(findex), zimage(findex))
    rcode = copyimage(vimage(findex), revimage(findex))
    rcode = copyimage(vimage(findex), uimage1(findex))

    'Set new calibration values to old ones (same image!)
    lincalib(findex) = lincalib(Me.tag)
    velcalib(findex) = velcalib(Me.tag)

    ' Set Dirty state of new window to True
    FState(findex).Dirty = True

    ' Paint and refresh this new window
    EnableToolBar

    Document(findex).Form_Resize
    Document(findex).Show
    FState(findex).Open = True
    Document(findex).form_paint

    Document(findex).Refresh

    GetRecentFiles

    Screen.MousePointer = 0

End Sub
Private Sub GetVicPalette(palette As OUR_PALETTE, image As imgdes)
    Dim palbytes As Long
    Static tmppal(0 To 255) As RGBQUAD
    Dim j As Integer

    palbytes = image.colors * 4

    getbmhifmemcpy tmppal(0), image.palette, palbytes
    For j = 0 To image.colors - 1
        palette.palentry(j).rgbRed = Asc(tmppal(j).rgbRed)
        palette.palentry(j).rgbGreen = Asc(tmppal(j).rgbGreen)
        palette.palentry(j).rgbBlue = Asc(tmppal(j).rgbBlue)
    Next j
End Sub

```

```

Private Sub SetVicPalette(palette As OUR_PALETTE, image As imgdes)
    Dim palbyts As Long
    Static tmppal(0 To 255) As RGBQUAD
    Dim j As Integer

    palbyts = image.colors * 4

    For j = 0 To image.colors - 1
        tmppal(j).rgbRed = (palette.palentry(j).rgbRed)
        tmppal(j).rgbGreen = (palette.palentry(j).rgbGreen)
        tmppal(j).rgbBlue = (palette.palentry(j).rgbBlue)
    Next j

    setbmhfmemcpy_ image.palette, tmppal(0), palbyts
End Sub

Private Sub mnuImageConvertGray_Click()
    'vimage(Me.Tag).imgtype = 1
    frmMDI.ActiveForm.UpdateUndo
    rcode = colortogray(vimage(Me.tag), vimage(Me.tag))
    frmMDI.ActiveForm.form_paint
    frmMDI.ActiveForm.Refresh
    FState(Me.tag).Dirty = True
End Sub

Private Sub mnuImageEdge_Click()
    UpdateUndo
    Dim redavg, grnavg, bluavg As Long

    rcode = calcavglevel(vimage(Me.tag), redavg, grnavg, bluavg)
    rcode = kodolith(redavg, vimage(Me.tag), vimage(Me.tag))
    rcode = outline(vimage(Me.tag), vimage(Me.tag))
    Me.form_paint
    Me.Refresh
    FState(Me.tag).Dirty = True
End Sub

Private Sub mnuImageFibrous_Click()
    UpdateUndo
    rcode = exchangelevel(0, 69, 0, vimage(Me.tag), vimage(Me.tag))
    rcode = exchangelevel(200, 255, 0, vimage(Me.tag), vimage(Me.tag))
    Me.form_paint
    Me.Refresh
    FState(Me.tag).Dirty = True
End Sub

Private Sub mnuImageInfo_Click()
    Info(Me.tag).lblTag.Caption = Me.tag
    Info(Me.tag).CalcInfo
    Info(Me.tag).Show
End Sub

Public Sub mnuImageMeas_Click()
    'set proper panel and item
    'Set frmMDI.tabCaseData.SelectedItem.Index = 4

    frmMDI.tabCaseData.Tabs(4).Selected = True
    frmMDI.fraCase(mintCurFrame).Visible = False
    frmMDI.fraCase(4).Visible = True

```

CLAIMS

1. A process for displaying images on a screen comprising the steps of:
providing an original image on the screen generated from a
matrix of intensity values and an original bitmap color table comprising
grayscale RGB values;
copying the original bitmap color table into a temporary bitmap
color array;
replacing the grayscale RGB values in the temporary bitmap
color array with assigned RGB values; and
refreshing the image on the screen to generate a colored
image without pixel saturation from the matrix of intensity values and
the assigned RGB values in the temporary bitmap color array.
2. The process of Claim 1, further comprising the step of creating a
temporary bitmap color array in a computer memory prior to the copying step.
3. The process of Claim 1, further comprising the step of analyzing at
least a portion of the refreshed image by performing calculations that are functions
of at least a portion of the matrix of intensity values that are associated with the
portion of the refreshed image.
4. The process of Claim 1, wherein the providing step further comprises
the steps of:
determining property characteristics of an object; and
translating the object property characteristics into the matrix of
intensity values.
5. The process of Claim 4, further comprising the step of analyzing at
least a portion of the object property characteristics by performing calculations that

are functions of at least a portion of the matrix of intensity values that are associated with the object property characteristics portion.

5 6. The process of Claim 1, wherein the providing step further comprises the step of using a device to measure property characteristics of an object and produce the matrix of intensity values from the measured property characteristics.

7. The process of Claim 1, wherein the providing step further comprises the step of using a digital imaging process to produce the matrix of intensity values.

10 8. The process of Claim 1, wherein the providing step further comprises the steps of:

 using an analog imaging process to produce analog signals
 representing property characteristics of an object; and

15 translating the analog signals into the matrix of intensity values.

9. The process of Claim 8, wherein the analog imaging process is echocardiography, the object is a part of a patient, and the property characteristics are densities of portions of the patient part.

20 10. The process of Claim 1, further comprising the steps of:

 replacing the assigned RGB values in the temporary bitmap
 color array with other assigned RGB values; and

 refreshing the colorized image on the screen from the matrix of
25 intensity values and the other assigned RGB values in the temporary
 bitmap color array to provide another image on the screen.

11. The process of Claim 10, wherein the replacing the assigned RGB
value step further comprises the step of replacing the assigned RGB values in the
30 temporary bitmap color array with the other assigned RGB values that are grayscale

RGB values.

12. A process for displaying images on a screen comprising the steps of:
generating on the screen a black and white image from a
matrix of intensity values in a CPU and a first permanent data storage
device comprising data representing a grayscale bitmap color table;
and

refreshing the image on the screen to generate a colorized
image without pixel saturation from the matrix of intensity values and
a second permanent data storage device comprising data
representing an other-than grayscale bitmap color table.

13. The process of Claim 12, wherein the first permanent data storage
device is a computer chip comprising the grayscale bitmap color table data in read
only memory and the second permanent storage device is another computer chip
comprising the other-than grayscale bitmap color table data in read only memory.

14. The process of Claim 12, wherein the first and second permanent data
storage device is a computer chip comprising the grayscale bitmap color table data
and the other-than grayscale bitmap color table data in read only memory.

15. Machine readable instructions adapted to direct the displaying of
images on a screen comprising:

an assignment portion adapted to assign an original bitmap
color table array of grayscale values of a black and white digital image
into the temporary bitmap color table array, wherein the black and
white digital image further comprises a matrix of intensity values;

a replacement portion adapted to replace the grayscale values
in the temporary bitmap color table array to assigned RGB values;
and

a refreshing portion adapted to refresh an image on a screen with a colorized image without pixel saturation from the matrix of intensity values and the assigned RGB values in the temporary bitmap color table array.

5

16. The instructions of Claim 15, further comprising an array creation portion adapted to create a temporary bitmap color array in a computer memory.

10

17. The instructions of Claim 15, wherein the instructions are in the form of computer software and/or computer hardware.

18. A method for colorization of a digital image without pixel saturation, said method comprising the steps of:

15

a) providing a digital image that includes an original bitmap color table as well as a matrix of intensity values;

b) copying the original bitmap color table into memory so as to create a Temporary Bitmap Color Table;

c) copying the original bitmap color table into the Temporary Bitmap Color Table to create a Temporary Palette Array;

20

d) replacing ranges of values on the Temporary Bitmap Color Table with assigned color values to create a Color-Modified Palette Array;

e) overwriting the original bitmap color table with the Color-Modified Palette Array while allowing the Original Matrix of Intensity Values to remain unmodified, and,

25

f) refreshing the image to generate a colorized image without pixel saturation.

19. A method for de-colorizing the colorized image obtained by the method of Claim 18, said method for decolorizing comprising the steps of;

30

g) replacing the color values assigned in step d with the grey-scale values of the original black and white image provided in step a.

FIGURE 1

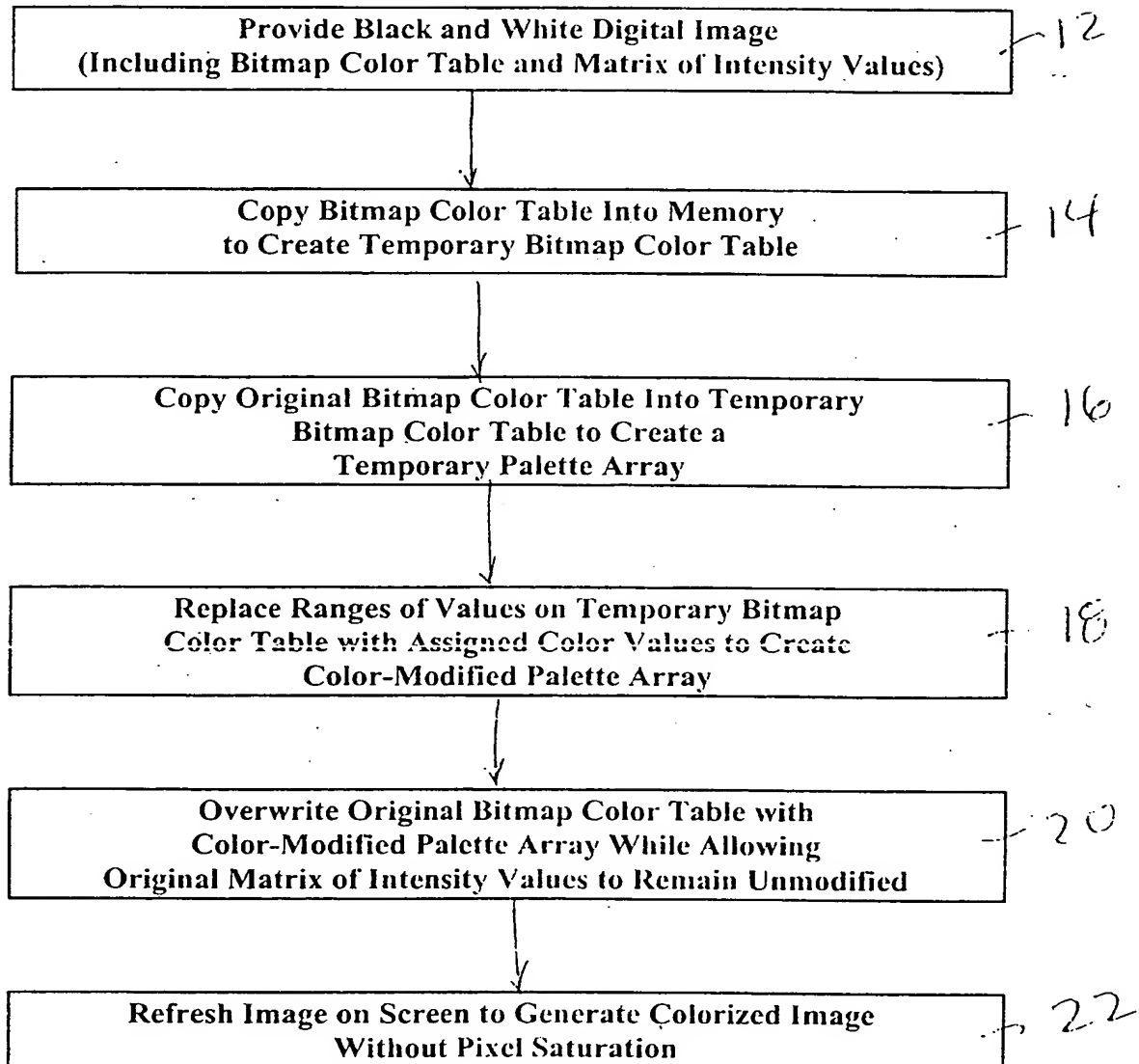


FIGURE 2

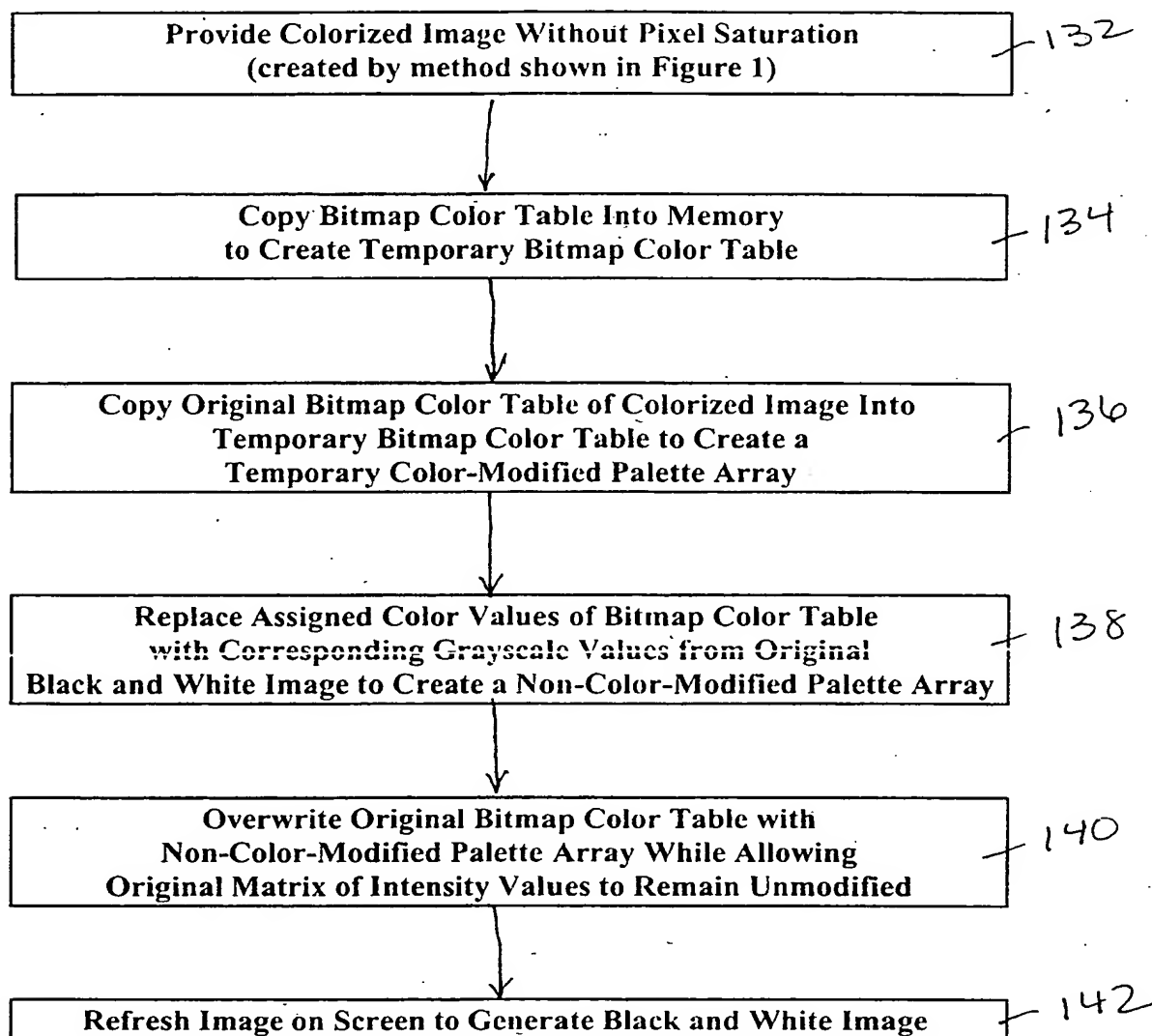


Fig. 3
5-chamber echo image opened and calibrated for distance

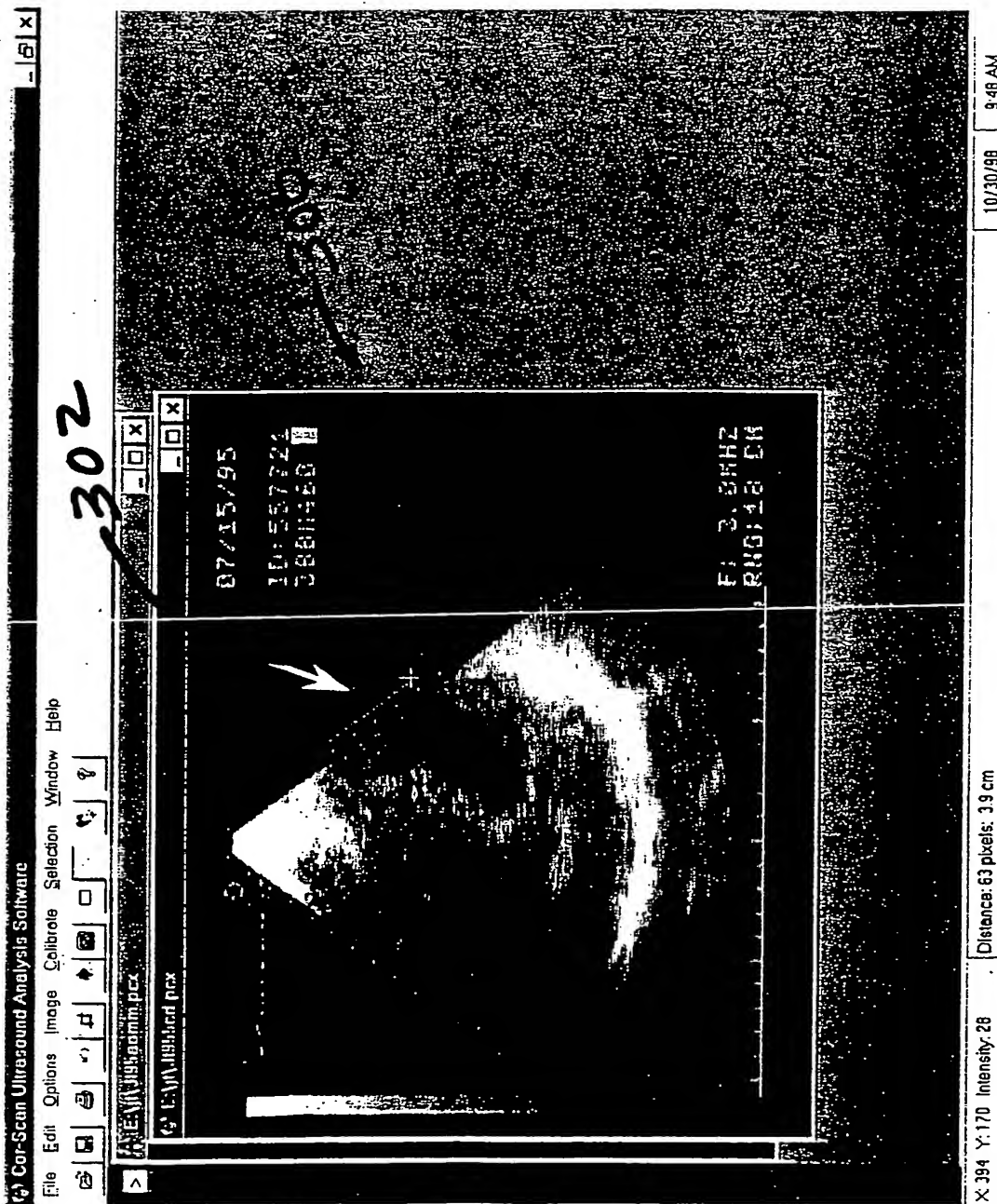


Fig. 4a

Automatic tissue analysis can measure percent fibrous tissue and calcium in the ventricle, carotid or other any other user defined region

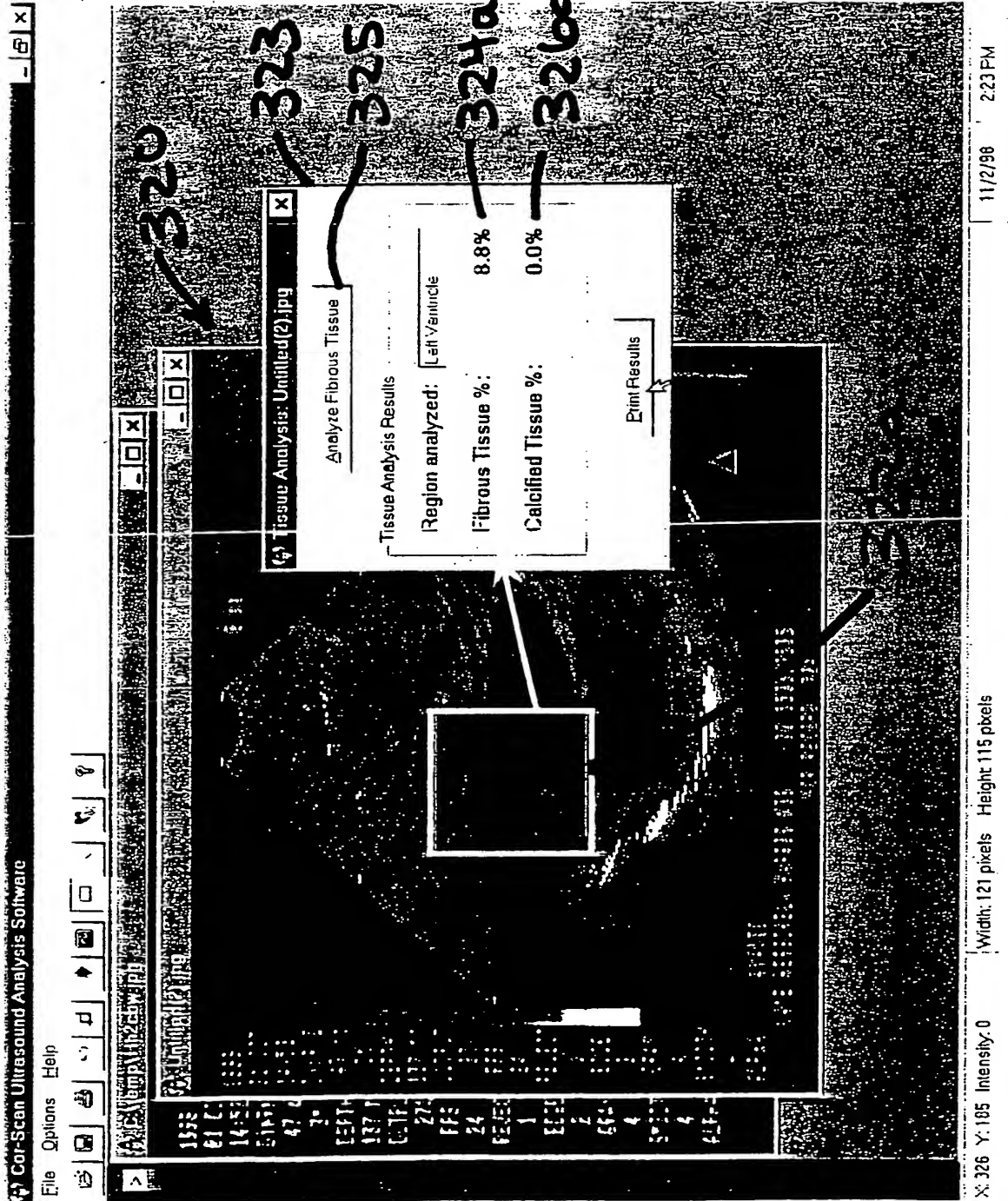
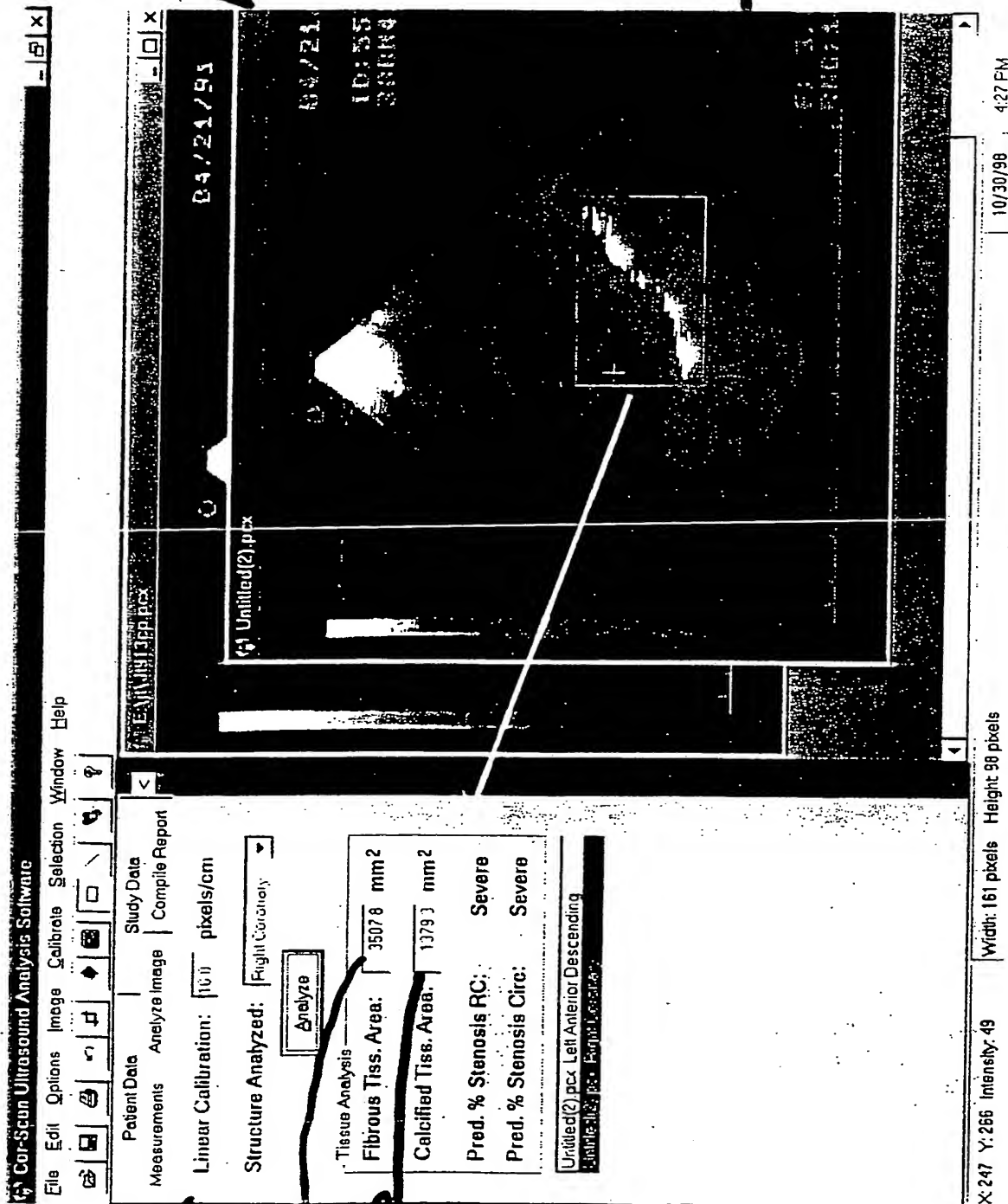


Fig. 4b

Automatic tissue analysis of right coronary and prediction of stenosis severity in the RC and the circumflex arteries



323

324b

326b

34C

322b

Fig. 5a

Density raster taken across right coronary artery.

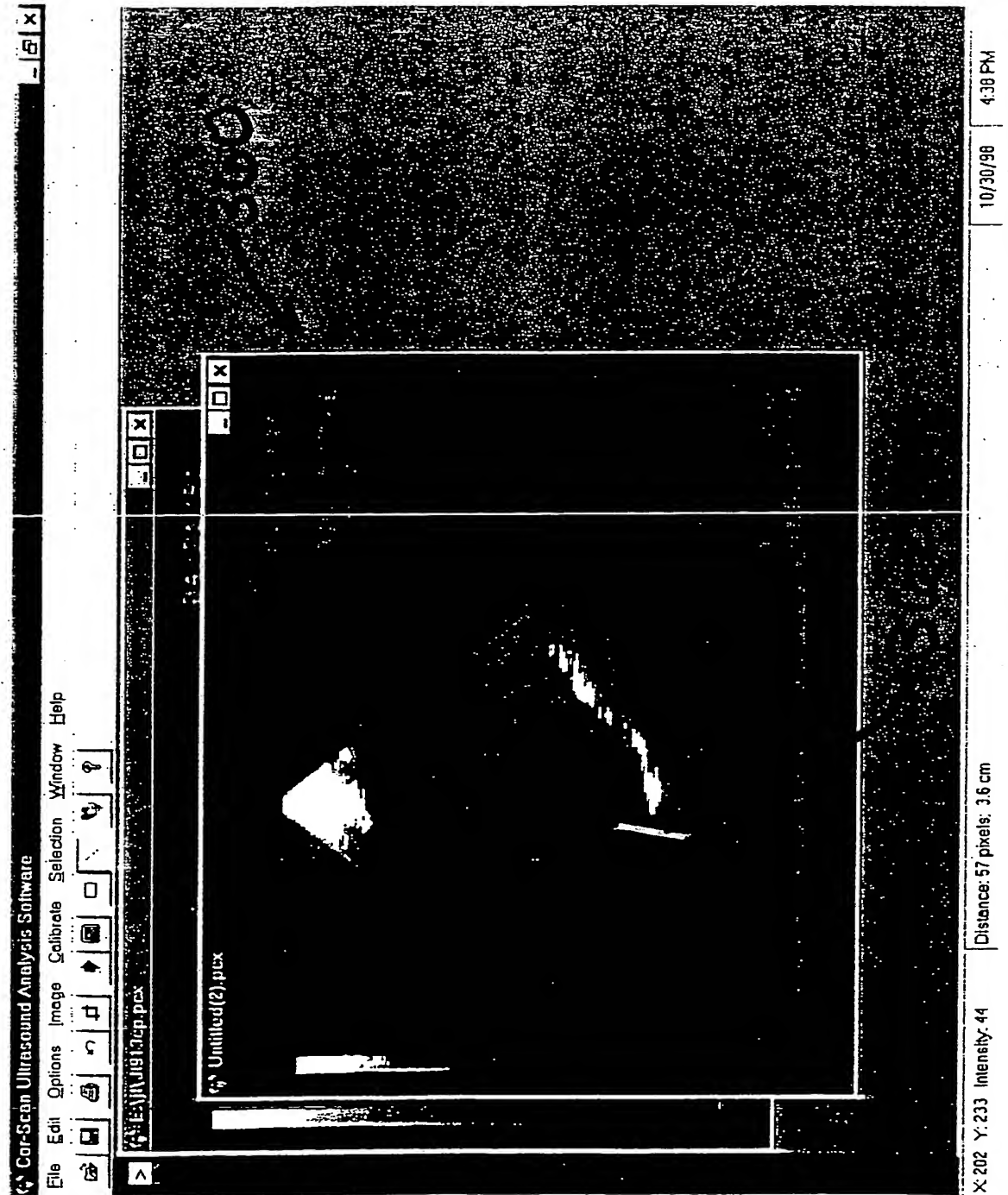
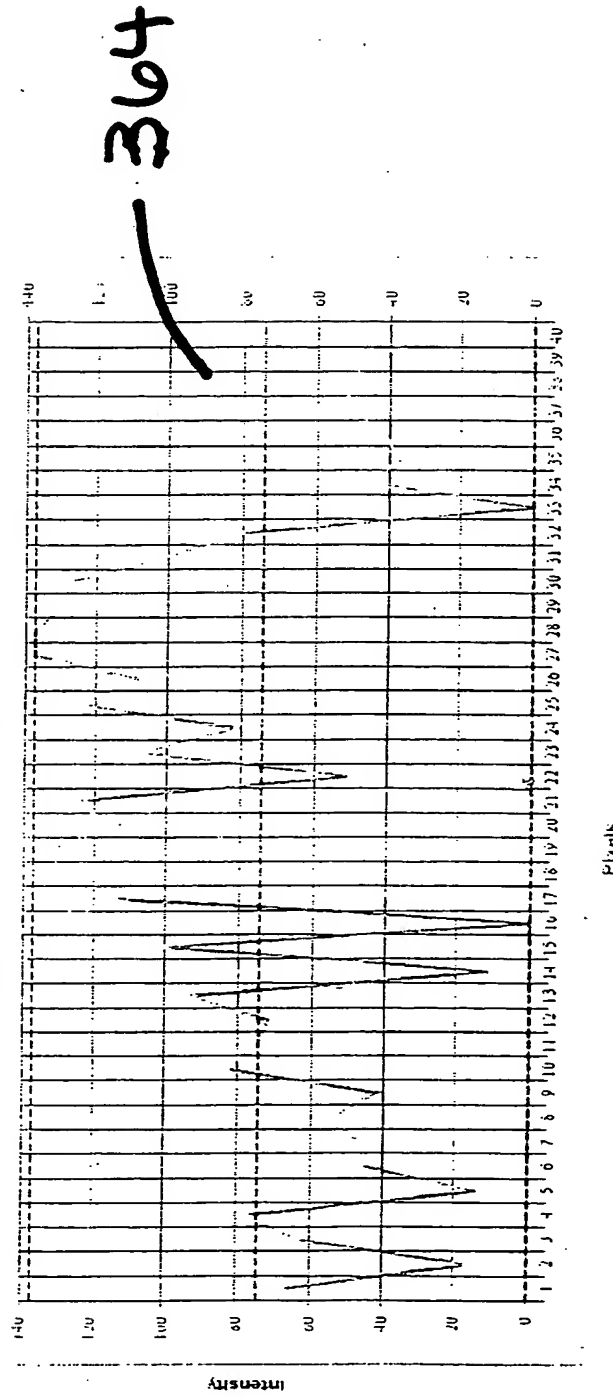


Fig. 5b

Density profile graph. Area from 16 to 33 pixels represents the density reflection profile of the right coronary artery

Cur Scan Density Profile: Untitled(3).pcx
Raster Graph Options

Raster Graph: Untitled(3).pcx



Estimate stenosis for

Coronary image

Estimate Stenosis

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US99/26218

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G06K 9/36; G09G 1/28

US CL :345/431, 432, 150, 153, 154, 199; 382/169, 206, 237

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 345/431, 432, 150, 153, 154, 199; 382/169, 206, 237

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WEST 12

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y,E	US 6,014,464 A (KURZWEIL et al) 11 JANUARY 2000, COLS. 14-15 & FIGS. 1 & 13 [DEVICES 16, 21, 30, 34].	1-16
Y,P	US 5,874,988 A (GU) 23 FEBRUARY 1999, FIG. 1.	1-16
Y	US H1506 A (BERETTA) 05 DECEMBER 1995, COL. 12; FIG. 1.	1-16

☐

Further documents are listed in the continuation of Box C.

☐

See patent family annex.

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O document referring to an oral disclosure, use, exhibition or other means	
P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

21 JANUARY 2000

Date of mailing of the international search report

29 FEB 2000

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